In re Patent Application of:
DOUGHERTY ET AL
Serial No. **10/629,143**
Filed: **JULY 29, 2003**

REMARKS

Claims 1-4 are pending in the present application.

Claims 1-4, which have been rejected, have been amended as set forth above.

The courtesies extended by Examiner Kang, during the telephone discussions with Applicants' attorney on even date herewith are gratefully appreciated. As was pointed out during these discussions by the undersigned, by virtue of the foregoing amendment, Applicants have made editorial corrections to the specification for purposes of clarity, and to comply with 37 C.F.R. § 1.75(d)(1), by providing antecedent basis in the Summary of Invention portion of the specification for the words and phrases employed in the amendments to claims 1-4. Reconsideration of this application in light of the foregoing amendments, the discussions of the above-mentioned telephone interview, and the following remarks is respectfully requested.

In the outstanding Office Action of September 26, 2005, claims 1-4 were rejected under 35 U.S.C. § 103 over Applicants' admitted prior art and further in view of the article by Rajarajan et al, entitled "Novel Polarization-Independent Optical Bends For Compact Photonic Integrated Circuits". The rejection set forth in paragraph 3, on page 2 of the Office Action, makes particular reference to lines 16-18 of the left hand column of page 463 of the article, stating the following:

> "Thus by developing a bent waveguide at these design parameters, polarization-<u>independent</u> bend can be realized." (emphasis added)

That portion of the article from which the above quote is taken makes reference to the radiation loss characteristic graphically shown in Figure 2, in the lower right hand column of page 463. In proximity to the left hand edge of the graph of Figure 2,

specifically at the denoted rib width of 1.4 μm, the solid radiation loss-representative graphical line, associated with TE polarization, intersects or crosses the dashed line therebeneath representative of radiation loss associated with TM polarization. This intersection or crossing of the radiation loss-representative curves for the two polarization modes (TE and TM) represents the point at specified geometric parameters of a bend the waveguide, in particular, waveguide thickness, rib width, and radius of curvature (bending radius) of the bend, can be defined so as to achieve the same loss for each of TE and TM polarizations within the bend, whereby a polarization-<u>independent</u> bend is realized. In the example given, polarization independence is achieved for a waveguide bend having a bending radius of 100 μm, waveguide thickness of 0.4 μm and rib width of 1.4 μm.

In paragraph 4 on page 4 of the outstanding Office Action, the Examiner makes reference to the fact the Applicants have argued that the Rajarajan et al article teaches exactly what it says, namely a polarization-<u>independent</u> bend; the present invention, on the other hand, addresses the problem of polarization <u>dependent</u> (not independent) loss, that is <u>compensated</u> by the bend in the waveguide to which the waveguide coupler is joined.

Paragraph 4 of the outstanding Office Action further refers to arguments by Applicants in the response to the previous Office Action of April 5, 2005, that the bend of the invention "nulls" a polarization dependence that occurs from the coupling portion. The Examiner asserts that she believes this to be the same as the bend that makes the polarization <u>independent</u> waveguide of Rajarajan et al (emphasis added).

Upon further review of the present application, in light of these and other comments made by the Examiner in the outstanding Office Action, Applicants have concluded that the use of the term "null" in connection with the functionality of the waveguide bend of the present invention, which is to <u>compensate</u> for polarization

dependent loss that had been introduced by the optical coupler upstream of the bend, is not clearly descriptive of the effect the bend has on the light coupled thereto from the coupler. Instead, as is described throughout the present specification, the purpose and functionality of the bend installed in the waveguide downstream of the coupler is to compensate for the differential coupling effects of respectively different polarizations of the light being coupled from the input optical waveguide to the tap branch, as the light passes through the coupler.

In the prior art, such as that described in US patent 5,539,850, referenced in the paragraph 11 bridging pages 3 and 4 of the specification, compensation for the differential coupling effects of a first directional coupler are achieved by a second compensating coupler having opposite optical characteristics, so that the preference for coupling a first polarization mode by the first coupler is offset or compensated by a preference for coupling the other polarization mode by the second coupler, with the net result being that the coupling imbalance between the two modes through the first coupler is compensated by an opposite or complementary imbalance effect of the second coupler, so that the overall effective coupling through the two directional couplers is effectively equalized for the two polarization modes. Namely, the overall effect of serially combining of two directional couplers in the compensated tap structure of the prior art is to realize no resultant or net polarization dependent loss from the input end of the waveguide to the output end of the tap.

Note that polarization dependent loss is as defined in paragraphs 4 and 5 on page 1 of the present specification. It is 10 times the log of the ratio of the maximum and minimum of transmission of the light with respect to all polarizations. By compensating for polarization dependent loss through the first directional coupler, by the addition of a second directional coupler that preferentially couples the opposite polarization mode therethrough, the overall loss for each polarization through both directional couplers of

the prior art waveguide tap structure is the same, which is equivalent to having no net polarization dependent loss from the input end to the output end of the waveguide tap.

The present invention is directed to an optical waveguide coupler arrangement that achieves the above-described polarization dependent loss compensation functionality of the two directional coupler-configured, waveguide tap arrangement of the prior art, but with significantly reduced hardware complexity and, therefore, less cost. This is accomplished by a novel waveguide tap structure that employs only a single directional coupler (rather than two couplers) and incorporating a relatively inexpensive section of waveguide bend into the second waveguide portion of the coupler. As is described, for example, in paragraphs [39] and [40] of the present specification, the addition of a small radius bend to a tap section of waveguide that is branched from the directional coupler imparts a polarization-dependent coupling effect to the light passing therethrough from the directional coupler, that is complementary or opposite to that of the directional coupler, and thereby compensates for the polarization dependent loss that is induced in the light by the directional coupler.

In other words, the desired polarization dependent loss compensation, that is achieved in the prior art by the addition of a second directional coupler to a first upstream coupler, is successfully realized in accordance with the present invention by a considerably simpler and less costly hardware combination of a single coupler and a waveguide bend coupled thereto.

By the foregoing amendments to claims 1-4, Applicants have endeavored to accomplish two objectives. The first is to avoid confusion that may have arisen by the previous use of the term "null" or similar language, which Applicants have concluded is the basis for the Examiner's assertion that she believes that the polarization dependence of the bend structure claimed by Applicants is the same as the polarization-independent bend described in the article by Rajarajan et al. The second objective is to more clearly

define the structure and the particular functionalities of respective portions of the structure of which the polarization compensated waveguide tap of the present invention is configured.

To this end, the preamble of claim 1 has been amended to recite a planar optical waveguide tap, in which polarization dependent loss is substantially compensated from an input end to an output end.

In addition to a first optical waveguide, the waveguide tap structure of claim 1 includes a second optical waveguide, that contains a coupling portion which couples light in a substantially polarization dependent manner. This substantially polarization dependent manner is defined by the fact that the first polarization mode couples significantly more strongly than the second polarization mode into the second optical waveguide from the first optical waveguide. Because of this stronger coupling of the first polarization mode, light of the second polarization mode experiences higher optical loss through the coupling portion than light of the first polarization mode. Namely, light coupled by the coupling portion experiences differential coupling for its first and second polarization modes.

To compensate for this differential coupling of the two polarization modes, the optical waveguide tap of claim 1 incorporates a bend portion into the second optical waveguide that is positioned between the coupling portion and the output end. The amendment to claim 1 specifies that the bend portion has a bend that transmits light therethrough in a substantially polarization dependent manner, so that light of the first polarization mode radiates out of the bend portion into a cladding about the bend portion with greater efficiency, and therefore experiences higher optical loss in the bend, than light of the second polarization mode. In other words, the bend provides a polarization-dependent transmission effect therethrough, that is complementary to that of the coupling portion of the second waveguide, downstream of which the bend is located. As

defined in the last clause of amended claim 1, this complementary polarization-dependent coupling effect of the bend substantially compensates for polarization loss that occurs from the coupling portion, for light which remains with the second optical waveguide after passing through the bend portion.

Applicants respectfully submit that the above-discussed manner in which claim 1 has been amended, to more particularly define the functionality of the respective portions of the waveguide on the light passing therethrough, particularly the complementary polarization dependent loss effects imparted to the two polarization modes of the light, as it passes through the coupling portion of the second optical waveguide, on the one hand, and the bend portion downstream thereof, on the other hand, clearly defines the placement and polarization dependent loss-compensating functionality of the bend portion of Applicants' tap.

Nowhere in their article do Rajarajan et al disclose or suggest the use or installation of a waveguide bend in an optical waveguide tap architecture, for coupling light therethrough in a substantially polarization-dependent manner, so as to compensate for the polarization dependent loss that is produced by an upstream waveguide coupling portion, from which light is transmitted to and passes through the bend. Simply put, the waveguide bend disclosed by the Rajarajan et al article is polarization-independent, whereas the bend employed in the waveguide structure of claim 1 produces a polarization-dependent effect on the light passing therethrough.

Amended claim 2 defines an optical waveguide system, in which the insertion loss of light coupled from the first waveguide to the second waveguide is different for first and second polarization modes, so that there is an insertion loss difference between the two modes. This claim defines the particular improvement, wherein a portion of the second optical waveguide has at least one bend for transmitting light therethrough in a substantially polarization dependent manner, so that a first polarization mode experiences

higher optical loss in the bend than the second polarization mode. Because the first polarization mode experiences a higher optical loss in the bend than the second polarization mode, the bend produces an insertion loss difference for the two polarizations, that is complementary to the insertion loss difference for the two polarizations of light coupled into the second optical waveguide from the first optical waveguide, and thereby compensates for that insertion loss difference.

As pointed out above in connection with claim 1, the article to Rajarajan et al contains no disclosure or suggestion of using polarization dependent loss, imported by a waveguide bend to light passing therethrough, to compensate for a complementary polarization dependent loss that has been imparted to the light, by an upstream waveguide to which the bend is connected.

Amended claim 3 defines a polarization compensated planar waveguide branch, that includes a planar optical trunk waveguide and a planar optical branch waveguide coupled to the trunk waveguide. Each of the trunk waveguide and the branch waveguide is capable of supporting both TE and TM modes.

The foregoing amendment to claim 3 more concisely defines the differential coupling losses experienced by the TE and TM modes, in the course of the light being coupled into the branch waveguide from the trunk waveguide, so that there is a coupling imbalance between the two modes. In addition, the wherein clause of claim 3 has been amended to delineate the fact that a downstream portion of the branch waveguide has a predetermined bend, with a predetermined radius for transmitting light therethrough in a substantially polarization dependent manner. As is the case with the bends employed in the waveguide structures of claims 1 and 2, the predetermined bend of the structure of claim 3 causes a higher optical loss in the polarization mode that experienced the lesser optical loss through the branch waveguide. The resulting effect of the bend is to compensate for the coupling imbalance between the two modes, as intended.

Again, as is the case with claims 1 and 2, the use of a waveguide bend to impart respectively different polarization-dependent losses, to respectively different polarization modes of light that have experienced complementary polarization-dependent losses in an upstream waveguide coupled to the bend, and thereby provide compensation of those polarization dependent losses, is not taught or suggested in the prior art, including the article to Rajarajan et al, the focus of which is establishing the design parameters of a waveguide bend, so that a polarization-independent (not dependent) bend can be realized.

Amended claim 4 delineates the improvement in a chip having a plurality of separate trunk waveguides within a common substrate, a respective trunk waveguide having a branch waveguide coupled thereto by a respective coupling region. The coupling region exhibits an imbalance in TE and TM mode coupling, thereby inducing polarization dependent loss for light coupled from the trunk waveguide to the branch waveguide. To compensate for this polarization dependent loss and thereby the imbalance in the TE and TM mode coupling, a downstream region of a branch waveguide includes a predetermined bend, for transmitting light therethrough in a substantially polarization dependent manner, and offsetting and compensating for the imbalance in TE and TM mode coupling that is exhibiting by the upstream coupling region, by way of which the branch waveguide is optically coupled to the trunk waveguide. The effect of this use of a waveguide region that transmits light therethrough in a substantially polarization-dependent manner, and thereby compensates for the polarization-dependent imbalance between the coupling for the respective modes, is to realize light transmission from the trunk waveguide, to the branch waveguide and passing through the bend, with a substantially reduced resultant or net polarization dependent loss.

Namely, like claims 1-3, claim 4, as currently amended, is believed to more concisely define the differential polarization dependent loss effects, that are imparted by the bend to respectively different polarization modes of light, as it is coupled through the

bend from an upstream coupling region or portion of waveguide, that has produced a differential coupling effect to respective polarizations of the light, that is complementary to the differential effect imparted to the respectively different polarization modes by the bend. Namely, the polarization dependent losses imparted to the respective polarization modes by the upstream waveguide coupler are compensated by complementary polarization dependent losses experienced by the respective polarizations, as they are transmitted through the bend downstream from the coupling region. Again, this serves to produce a substantially reduced resultant or net polarization dependent loss, as compared to the case where the polarization-dependent loss compensating bend is not employed.

In view of the manner in which the claims have been amended to more concisely define the polarization-dependent loss compensating effects imparted by a waveguide bend installed or coupled downstream of a waveguide coupler, that imparts complementary differential polarization-dependent losses to respectively different polarizations of the light passing therethrough, which structure and functionality are not disclosed or suggested by the prior art cited in the outstanding Office Action, a notice of patentability of claims 1-4 is respectfully requested. It is also respectfully requested that the amendment be entered, not only because the foregoing amendments are believed to place the claims in condition for allowance, but because the amendments clarify terminology employed in the specification and, pursuant to Rule 75(d)(1), provide antecedent basis in the specification for the wording in the current amendments to the claims.

Favorable reconsideration of this application and a notice of allowance of claims 1-4 are respectfully requested.

Should any minor informalities need to be addressed, the Examiner is encouraged to contact the undersigned attorney at the telephone number listed below.

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Respectfully submitted,

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I HEREBY CERTIFY that the foregoing correspondence has been forwarded via facsimile number **571-273-8300** to MAIL STOP AF, COMMISSIONER FOR PATENTS, this 13 day of December 2005.